

LOCATION BASED HANDOFF FOR MOBILE DEVICES

DESCRIPTION

The present invention relates to the communications arts. It finds particular application in the wireless local area network systems (WLAN) and will be described with particular reference thereto. However, the invention may also find application in other communications systems.

WLAN is a flexible data communications system implemented as an extension to, or as an alternative for, a wired local area network (LAN). Typically, WLAN uses radio frequency (RF) technology to transmit and receive data over the air without relying on any physical connection. The data being transmitted is superimposed on the radio carrier so that it can be accurately extracted at the receiving end. Multiple radio carriers exist in the same space at the same time without interfering with each other, provided that the radio waves are transmitted on different radio frequencies. To extract data, a radio receiver tunes in one frequency while rejecting all other frequencies.

In a typical WLAN system, a transmitter/receiver device, called an access point, connects to the wired network from a fixed location using standard cabling. Typically, the access point receives, buffers, and transmits data between the WLAN and the wired network infrastructure. Generally, a single access point supports a small group of users and can function in a range of approximately thirty to fifty meter radius. End users access the WLAN through WLAN adapters, which are implemented as PC cards in notebook or palmtop computer, as cards in desktop computers, or integrated within handheld computers. WLAN adapters provide an interface between the client network operating system (NOS) and the airways via antenna.

Generally, in a large facility such as an office, a hospital, a manufacturing facility, or the like, it is necessary to install more than one access point. The access points are installed to blanket the area with overlapping coverage cells so that the clients can roam seamlessly throughout the area without ever losing contact. When a client moves from one area to another, a handoff has to be performed to assign new system resources associated with the new access point. The handoff involves executing a set of negotiations between the mobile device and a central computer. As a result, the client is handed over from one access

point to another in a way that is invisible to the client. Generally, a handoff improves performance of the system at the expense of tying up more system resource.

Efficient and timely handoff procedures are very important within the WLAN which has small operating cells and great demand for increased communications system capacity. A typical approach for a mobile device handoff is to scan all radio frequencies within the WLAN operational space to determine a relative strength of the mobile device signal. However, with many users being hooked up to the WLAN and numerous crossings of cells boundaries, this approach considerably ties up system resources and slows down communications throughput.

There is a need for technique that provides adaptive, fast, efficient, seamless, and cost effective handoff of mobile units in WLAN. The present invention contemplates a new and improved method and apparatus that overcomes the above-reverenced problems and others.

In accordance with one aspect of the present invention, a communications system is disclosed. A plurality of mobile wireless units and a plurality of access points, each surrounded by an associated operational cell, are located within a defined area of a WLAN. The operational cells are overlappingly disposed in the defined space. Each access point operates at a dedicated frequency. A means tracks a movement of at least one mobile device within the defined space. A means scans identified scanning frequencies of nearby access points to measure actual signal strengths between the at least one mobile device and each of the nearby access points. A means calculates at least a position of the at least one mobile device by comparing the actual signal strengths with a map of relative signal strengths at predefined locations in the defined space. A means assigns an access point with a strongest signal to the at least one mobile device based on its location and the map of relative strengths in the defined space.

In accordance with another aspect of the present invention, a method for handing off at least one mobile device from one access point to another in a wireless local area network is disclosed. A movement of the at least one mobile device within the defined space is tracked. Identified scanning frequencies corresponding to each of an identified plurality of nearby access points are scanned. Actual signal strengths at each of the identified frequencies between the at least one mobile device and the identified access points are measured. At least a position of the at

least one mobile device is calculated by comparing the actual signal strengths with a map of relative signal strengths at predefined locations in the defined space. An access point with a strongest signal is assigned to the at least one mobile device based on the calculated position and the map.

5 One advantage of the present invention resides in the fast and efficient handoff of the wireless mobile units in the wireless local area network.

 Another advantage resides in the cost effective handoff.

 Still further advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following
10 detailed description of the preferred embodiments.

 The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for
15 purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

 FIGURE 1 schematically shows a portion of a WLAN communications system; and

 FIGURE 2 schematically shows a part of a WLAN communications system
20 in accordance with the present application.

 With reference to FIGURE 1, a wireless local area network 10 includes one or more mobile devices or units 12₁, 12₂, ..., 12_n. Preferably, the mobile devices 12₁, 12₂,
25 ..., 12_n are palm computers, notebook computers, held-hand devices, PDAs, pagers, desktop computers, or any other devices which can be configured for wireless communications. Generally, the network 10 couples multiple access points or stations 14₁, 14₂, ..., 14_n (only six access points are shown for simplicity of illustration), which are distributed throughout a defined area or space 16 to provide wireless service to the mobile
30 devices 12₁, 12₂, ..., 12_n which operate within the space 16 and are configured to communicate with the access points 14₁, 14₂, ..., 14_n. Each access point 14₁, 14₂, ..., 14_n has a finite operational range or access point cell 18₁, 18₂, ..., 18_n, which is typically 30-50

meters. Each access point 14₁, 14₂, ..., 14_n operates within its own dedicated radio channel with a known radiofrequency. Because the operational ranges 18₁, 18₂, ..., 18_n overlap within the area 16, each channel operates at a unique radiofrequency to prevent concurrent communications of the mobile device 12₁, 12₂, ..., 12_n with more than one access point at
5 the same frequency. Of course, it is also contemplated that other WLAN designs can be used, in which the frequencies can be reused.

The access points 14₁, 14₂, ..., 14_n are wired or otherwise connected into a wired network infrastructure or a local area network 20. A central computer 22, which is connected to the local area network 20 and includes associated software means 24 and
10 hardware means or processor 26, oversees the operations of the WLAN system 10 and, preferably, provides an interface to various systems and/or applications which are available within the local area network 20.

Each access point 14₁, 14₂, ..., 14_n includes an antenna or receiving/transmitting means 30 to communicate bi-directionally with the mobile devices
15 12₁, 12₂, ..., 12_n. E.g., the access points 14₁, 14₂, ..., 14_n at least receive, buffer, and transmit data between the mobile devices 12₁, 12₂, ..., 12_n and the wired network 20. Each mobile device 12₁, 12₂, ..., 12_n includes associated hardware means 32 and software means 34. The hardware and software means 32, 34 are implemented or integrated into the mobile devices 12₁, 12₂, ..., 12_n to provide an interface between the mobile devices 12₁, 12₂, ..., 12_n
20 and the receiving/transmitting means 30.

With continuing reference to FIGURE 1, when the mobile device 12₁ is in the cell 18₁, it communicates with the access point 14₁. As the mobile device 12₁ moves within the defined area 16, the processor 26 executes a set of instructions and, if the handoff is determined to be necessary, handoffs the mobile unit 12₁ to another access point as will
25 be discussed in a greater detail below.

With reference to FIGURE 2, an initial signal strengths determining means or computer routine or algorithm 38 determines initial signal strengths, i.e. signal gradients, at predefined locations. Optionally, the initial signal strengths determining means 38 defines the initial signal strengths at the predefined locations statistically. A
30 mapping means 40 maps the initial signal strengths into the defined space 16. A two- or three-dimensional geographical signal strength map of the area 16 indicating all of the stations or access points 14₁, 14₂, ..., 14_n, associated operational frequencies, and the

defined initial signal strengths are stored in a database or an area map memory 42. Preferably, the database 42 is located at the central computer 22. Optionally, the database 42 is located within the WLAN 10, e.g. at the mobile device 12₁, 12₂, ..., 12_n.

5 A handoff means or computer routine or algorithm 48 executes an access point assignment and subsequent handoff to the closest access points for determined locations and identifies a channel with the strongest signal, e.g. the best signal to noise ratio, of the mobile devices 12₁, 12₂, ..., 12_n within the defined space 16. More specifically, when one of the mobile units 12₁, 12₂, ..., 12_n, such as the mobile unit 12₁, is powered up, a position determining means or computer routine or algorithm 50 determines
10 the location of the mobile device 12₁ within the defined space 16. A scanning means or computer routine or algorithm 52 scans operational frequencies of the channels of all the access points within the defined space 16 to determine gradients of actual signal strengths between the mobile device 12₁ and each of the scanned frequencies. The scanned frequencies are presented in an order of the gradients, e.g. from the highest gradient to
15 lowest, and are stored in a scanned frequencies memory 54. A position calculating means or computer routine or algorithm 56 calculates a position of the mobile device 12₁, e.g. the initial position P1, by comparing the actual signal strengths against the mapped signal strengths. Preferably, the position is determined from the relative signal strengths of the three strongest frequencies, normally the three closest stations. However, other numbers of
20 frequencies/stations for determining the position of the mobile units can be used. A larger number gives greater positional accuracy. In some instances, less than three may identify the location of the mobile unit uniquely, particularly when walls and other physical obstructions are considered.

The determined position P1 is stored in a position memory 58. An access
25 point assigning means or computer routine or algorithm 60 identifies a location of an access point with the strongest signal and assigns it to the mobile device 12₁. A scanning frequencies identifying means or computer routine or algorithm 62 identifies frequencies of, preferably three adjacent channels, e.g. three access points 14₁, 14₃, 14₄ which are closest to the position P1 which typically have the strongest signals. The three adjacent
30 access points and corresponding frequencies of each associated channel are stored in a scanning frequencies memory 64.

As the mobile device 12₁ moves from the position P1 towards position P2, the signal strength between the mobile device 12₁ and the access point 14₁ is declining and signal strength between the mobile device 12₁ and the access points 14₃ and 14₄ is increasing. With the defined space 16 being mapped, the scanning means 52 periodically scans the three stored adjacent frequencies to collect the signal strength values between the mobile device 12₁ and the frequencies of the three closest access points as the mobile device 12₁ moves from the position P1 toward the position P2. The position calculating means 56 calculates a new position of the mobile device 12₁. Preferably, the exact position of the mobile device 12₁ is triangulated by comparing the actual signal strengths at the three measured frequencies. A velocity determining means or computer routine or algorithm 66 compares location results of the periodic scanning and determines speed and direction of movement of the mobile device 12₁ or any other mobile device within the defined space 16. Based on the speed and direction of the mobile device, a future position predicting means or computer routine or algorithm 68 predicts future positions of the mobile device as well as projected future signal strengths between the mobile device and access points of the cell in which the mobile device is located and adjacent cells.

If it is determined that the mobile device 12₁ is approaching a new position, e.g. the position P2, at which the map 42 shows a different access point will have stronger signal, the access point assigning means 60 assigns the mobile device 12₁ a new primary communication access point which, preferably, has the strongest signal. By consulting the map 42, the scanning frequencies identifying means 62 identifies the frequencies of the, preferably, three access points 14₁, 14₄, 14₆ that provide the strongest signals with the new position P2. In this example, the three access points which measure location stay the same, but the access point through which communication occurs shifts from 14₁ to 14₃.

As the mobile device moves toward location P3, one of the three location measurement access points changes, i.e., the three closest change from 14₁, 14₃, and 14₄ to 14₃, 14₄, and 14₆. The change over from access point 14₁ to 14₆ is preferably done at the time which the position predicting means predicts the mobile device will become closer to access point 14₆ than to access point 14₁. In this manner, if the mobile device is moving so fast compared to the location sampling interval that it will be out of range of access point 14₁, it will still seamlessly triangulate its position off of access points 14₃, 14₄, and 14₆. The three new adjacent access points and corresponding frequencies of each associated

channel are stored in the scanning frequencies memory 64 to be periodically analyzed by the position determining means 50 to monitor the position of the mobile device 12₁. The AP assigning means 60 accesses the map 42 and the scanning frequencies memory 64 to retrieve the frequencies of the new access point 14₆ and the discontinued access point 14₁.
5 This frequency change is communicated to the mobile device to cause a seamless change in the scanning frequencies without searching all frequencies looking for the new closest access points.

With continued movement to P3, the communication frequency is changed from the frequency of access point 14₃ to the frequency of access point 14₆.

10 In some circumstances, the access point assigning means 62 may not assign a mobile unit to the access point with the strongest signal. The access point assigning means 60 confers with an arbitration means or computer algorithm 70 to determine the best overall distribution of the assignment of the mobile devices to the access point. In one example, the arbitration means 70 looks to see if any access point is over-crowded or
15 approaching capacity. If a mobile unit is approaching a near capacity access point, the handoff is deferred until the map 42 shows it is moving beyond a signal strength of its current access point or another mobile device moves out of the over-crowded access point's region. As a second example, the arbitration means 70 projects how long the mobile unit will be in the new access point region from the trajectory of its projected
20 velocity and the map. If the projected trajectory will only pass briefly through the new zone without losing satisfactory signal strength from its current access point or the next yet projected access point, the handoff from the current access point to the next access point and from the next access point to the next yet access point can be skipped in favor of a handoff directly from the current access point to the third next yet access point.

25 With continuing reference to FIGURE 2 and further reference to FIGURE 3, to improve the accuracy and reliability of position tracking, more than three scanning frequencies of the neighboring access points are selected for scanning to track the position of the mobile device 12₁, 12₂, ..., 12_n. The number of the adjacent access points (scanned frequencies) varies as a function of the certainty of the position accuracy to minimize the
30 number of channels to be scanned to determine the accurate position of the mobile unit 12₁ as it moves within the defined area 16. As position becomes less certain, more nearby

access points are scanned; as the position becomes more certain, fewer access points are scanned.

More specifically, as the position calculating means 56 determines the position of the mobile device 12₁, a certainty determining means 72 determines a certainty of accuracy of the determined location based on prespecified factors such as longer intervals between samplings, motion at high rate of speed, motion along an erratic trajectory, or the like. The determined certainty is compared with a threshold which is preferably predetermined in advance based on certain criteria. Of course, it is also contemplated that the threshold can be varied to restrict or increase the number of scanned frequencies based on the system requirements. If the determined certainty is below the threshold, the scanning frequencies identifying means 62 accesses the area map database 42 and selects all operational frequencies existing within the area 16 for scanning. The scanned frequencies are presented in an order of the gradients, e.g. from the highest gradient to the lowest, and are stored in the scanned frequencies memory 54. The position calculating means 56 recalculates the position of the mobile device 12₁, and the certainty determining means 72 determines the certainty of the recalculated position. The redetermined certainty is compared with the threshold. If the determined certainty is still below the threshold, the position calculating means 56 requests more frequencies from the scanned frequencies memory 54. The certainty determining means 72 recalculates the certainty each time an additional frequency is added to the position calculation and compares the determined certainty with the threshold until the threshold is reached and/or exceeded. The identified optimal adjacent access points and corresponding frequencies are stored in the scanning frequencies memory 64 to be scanned by the scanning means 52 to determine the speed and position of the mobile device 12₁ with more accuracy.

The invention has been described with reference to the preferred embodiments. Modifications and alterations will occur to others upon reading and understanding of the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.